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Environmentally Conscious Technologies

Does Green Equal Competitive Advantage?

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COVER STORY

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Environmentally Conscious Technologies

Does Green Equal Competitive Advantage?

Every electronics manufacturing company will be affected by the rise of green activities. The choice is to take advantage of the growing demand for greener products or face ten years of costly, stressful environmental fire drills. Like it or not, the greening trend is real, powerful, and driving every industry toward what the Europeans call "sustainable manufacturing" by using environmentally conscious technologies (ECT).

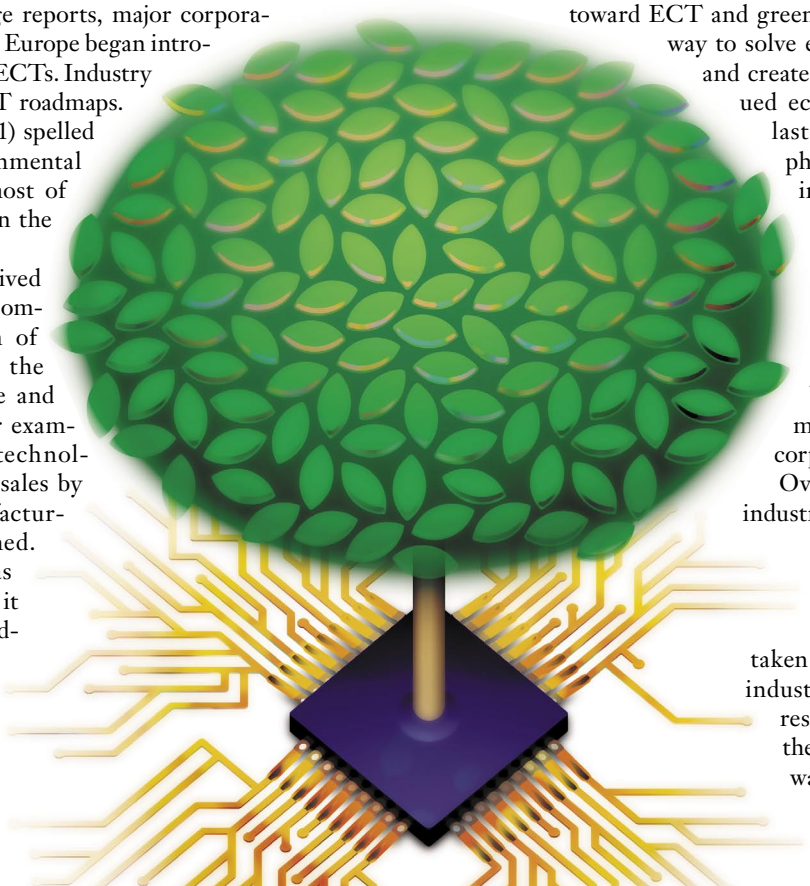
The notion of ECT dates back to the 1970s when the oil embargo stimulated entrepreneurial activity in solar and wind technologies. When the embargo ended, this activity slowed. Currently, investments in clean energy to reduce risks concerning the supply of energy, as well as climate change, have skyrocketed.

Environmentally conscious technologies within the electronics industry began in earnest in the mid-90s. Spurred by early waste, toxicity, and resource-usage reports, major corporations in the U.S., Japan, and Europe began introducing electronics-specific ECTs. Industry associations developed ECT roadmaps. A previous article (Figure 1) spelled out technologies, environmental needs, and timeframes, most of which have been realized in the past six years.

ECTs, and products derived from them, are rapidly becoming not only a condition of doing business, but also the ticket to growing revenue and profit. In March 2007, for example, Toyota's hybrid technology boosted its U.S. auto sales by 13%; all U.S. auto manufacturers' market share declined. General Electric (GE) has announced that, by 2010, it expects to sell $20B in products that mitigate environmental problems.

In the electronics manufacturing industry, we should expect the same. Numerous studies have highlighted the need for greener ECTs, products, and opportunities for companies that provide them. For example, manufacturing a single desktop PC and a 17" monitor takes at least 240 kg of fossil fuels, 2,200 kg of chemicals, and 1,500 kg of water — the weight equivalent of a mid-size car. On the wafer level, Table 1 shows the estimated input and output for a single wafer, a single fab, and a projected 120 new fabs that may be built to meet the world's wafer requirements.[1] End-of-life electronic waste (e-waste) is the fastest-growing waste stream, with an approximate 18-year-doubling rate. When burned or buried at disposal, those products release highly toxic materials. Furthermore, recycling those products requires a great amount of energy.

The upshot is that there is a growing recognition that, in the next several decades, we will be part of a worldwide movement toward ECT and greener products, as the only way to solve environmental problems and create a foundation for continued economic growth. In the last decade, more geographies have been promoting ambitious legislation. From that perspective, RoHS and WEEE are two legislative stepping stones in a broader path toward "sustainable manufacturing" that is being set by the world's most powerful nations and corporations.



Overall, the greening of the industry has gone mainstream. Perhaps the most surprising aspect of this has been the degree of market leadership taken by companies in every industry sector. Rather than resisting the trend outright, they have embraced it with a wave of ECTs and greener

Table 1. Wafer Fabrication Input/Output			
	One 6" wafer	One fab: 5,000/wk/52 wks	Projected 120 new fabs
Input			
Bulk gases (cu. ft.)	3,200	832,000,000	99,840,000,000
Hazardous gases (cu. ft.)	22	5,720,000	6,864,000,000
Deionized water (gal.)	2,275	5,200,000	624,000,000
Electrical power (kW/hr.)	285	74,100,000	8,892,000,000
Output			
Sodium Hydroxide (lbs.)	25	6,500,000	780,000,000
Hazardous waste (lbs.)	7	1,820,000	218,400,000

IN SUMMARY:

As we approach the 5th anniversary of the EU's enactment of the RoHS and WEEE Directives, it is time to reflect on what has occurred and what likely will occur. Questions arise, such as: Is there an end in sight to green activities? What should companies do? This article addresses these questions and offers manufacturers recommendations for capitalizing on the greening of the electronics industry.

products that reduce materials, energy, and water input, as well as toxic outputs. Within that context, the electronics industry is a microcosm. Companies are incorporating design-for-recyclability (DfR) as a key part of their design-for-environment (DfE) implementations. Recently, a consortium of corporations and non-governmental organizations (e.g. Motorola and Greenpeace) petitioned the EU, arguing that 11 member states, including France, Spain, and the U.K., inadequately implemented WEEE's individual producer responsibility provisions, thereby reducing DfE incentives.

Regarding energy use, HP and many other companies have invested large sums of R&D dollars to improve performance. Companies now see that the growing worldwide movement to reduce carbon emissions will create a market demand for energy-efficient products. Legislatively, Australia has established the Minimum Energy Performance Standards, and a U.S. bill was signed in December 2006 to study and promote the use of energy-efficient servers.

Regarding toxicity, we have become highly sensitive to the chemical composition of the materials used to make products — and to the financial risks of not doing so. While the greening trend may have had its beginnings in lead-free assembly processes, it now has extended to the RoHS 6 substances, the 15 JIG-A substances, and to corporate-wide materials-of-concern programs that include a hundred or more substances. For instance, one EMS provider is being driven by a major customer to reduce or eliminate substances beyond RoHS requirements. Another manufacturer, who is exempt from EU RoHS and WEEE, was blindsided by a request for compliance information on 1,100 parts from one of its three largest customers. A third company was spurred to action by a broad materials-of-concern program initiated by its corporate parent. The common thread in these examples is customer demand to implement greener ECTs; produce greener products; and/or perform substance-level analysis, roll-up, and substitution. This is a critical point that bears noting because too many companies focus solely on governmental activity. They mistakenly believe that, because there

Component Manufacturing Technologies	Environmental Needs	Timeframe
General	Reduce lead, cadmium, Hg <100 ppm	2001–2002
	Improve energy efficiency	Ongoing
	Decrease resource usage	Ongoing
Interconnect substrates	Eliminate brominated flame retardant	2002–2004
	Eliminate lead (e.g. HASL finishes)	2001–2002
	Increase recycling during production	Ongoing
	Decrease resource usage	Ongoing
	Eliminate hazardous solvents and materials such as glycol ethers	Ongoing
	Increase equipment re-use	Ongoing
Ceramic substrates	Eliminate beryilia substrates	2004–2006
	Decrease energy usage	Ongoing
Displays	Eliminate Hg in lamps	2001–2002
	Eliminate lead-based glass seals	2004–2006
	Reduce material use during production	Ongoing
	Increase recycled content	Ongoing
	Improve energy efficiency	Ongoing
Mass data storage	Increase recycled content	Ongoing
Optoelectronics	Increase recycled content	Ongoing
Digital and mixed-mode semiconductors	Reduce water and energy use	Ongoing
	Decrease emissions during manufacture	
	Improve device power management	Ongoing
Energy storage systems	Replace NiCd technology	Ongoing
	Improve energy efficiency	Ongoing
	Increase battery life	Ongoing
RF components	Increase temperature capability for new solders	2000–2002
Passive components	Increase temperature capability for new solders	2000–2002
	Increase recycled content	Ongoing
	Eliminate lead-based frits	2002–2004

Figure 1. Component manufacturing technologies. *Photo courtesy Evans, Holly.*

has been little enforcement activity in the EU to date, they are "safe" to sell products that are known to be non-compliant or that rely on notoriously unreliable Yes/No supplier certificates. While it is impossible to believe that there will not be an increase in enforcement action from Denmark, Germany, the Netherlands, Sweden, and other EU countries known for their aggressive environmental policies — not to mention Australia, Brazil, Canada, China, Japan, Korea, the U.S., and all the other geographies with similar legislation — the biggest stick will continue to come from customers who will go elsewhere to find greener products if current suppliers are incapable of providing them.

Item(s) found containing substance: Antimony compounds (Antimony trioxide and pentoxide)

Total Number of Items Sampled:	1571
Total Number of Items with Substance Present:	11
% of Items with Substance Present:	.7

Part Name	Supplier Part #	Rev Level	Rev Date	Supplier Name	A	B	C	R	E
DIO,SMT,SHT,SOD123,30V,1A,P	MBR130LSFT1G			ABC SEMICONDUCTOR	N	N	Y	Y	7a
DIO,SMT,SIG,SOT23,70V,200MA,	BAW56LT1G			ABC SEMICONDUCTOR	Y	N	Y	Y	
DIO,SMT,SIG,SOT23,70V,200MA,	BAV70LT1G			ABC SEMICONDUCTOR	Y	N	Y	Y	
DIO,SMT,ZEN,SOT23,12V,5MA	BZX84C12LT1G			ABC SEMICONDUCTOR	Y	N	Y	Y	
DIO,SMT,ZEN,SOT23,3.6V,225M	BZX84C3V6LT1G			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SO14,74ACT32,TTL,5V,C,	MC74ACT32DG			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SO14,74ACT32,TTL,5V,C,	MC74ACT32DR2G			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SO8,MC33502,AMP,1/7V,	MC33502DG			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SO8,MC33502,AMP,1/7V,	MC33502DR2G			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SOW20,74ACT273,TTL,5	MC74ACT273DWG			ABC SEMICONDUCTOR	Y	N	Y	Y	
IC,SMT,SOW20,74ACT273,TTL,5	MC74ACT273DWR2G			ABC SEMICONDUCTOR	Y	N	Y	Y	

A JIG "A List" Compliance B JIG "B List" Compliance C "C List" Compliance R RoHS Compliance E RoHS Exemptions

Y Compliant N Non-Compliant U Unknown

Figure 2. Substance analysis report.

Anticipated Trends

The EU will remain the environmental legislation epicenter. For the last three years, the EU has been the world's largest industrialized market with the world's largest gross domestic product (GDP). Recently, Thomson Financial reported that, for the first time since before World War I, Europe passed the U.S. in overall stock market capitalization ($15,720B compared to $15,640B). What this likely means is that the EU will continue to be the epicenter of legislatively driven shifts in how products are made, used, and disposed. For example, the Energy using Products (EuP) Directive will drive ecological profiles and life-cycle analyses; the Registration, Evaluation, and Authorization of Chemicals (REACH) Directive will send manufacturers scurrying to gather chemical-usage information and limit their financial exposure; and the EU's aggressive goal of reducing energy usage 20% by 2020 will force product innovation in virtually every industry.

The U.S. will reclaim much of its environmental leadership. California has already passed its Global Warming Solutions Act and its Million Solar Roofs Initiative; eight states, including Vermont and Rhode Island, currently regulate external power supplies; Washington, Oregon, California, Arizona, and New Mexico are developing a regional carbon-emissions cap-and-trade platform; and 385 mayors have signed the U.S. Mayors Climate Protection Agreement.

At the federal level, a U.S. Supreme Court ruling paves the way for the EPA to regulate carbon emissions. The U.S. Air Force is the third largest purchaser of green energy. In the U.S. Congress, there are eight climate-change bills, a select committee on Energy Independence and Global Warming, and a strong likelihood that RoHS-like legislation will be introduced.

Other economically developed nations

RoHS on Paper

The industry's relationship to solder has changed drastically since the EU's July 1, 2006 RoHS implementation date. Most low- to mid-volume EMS providers in the U.S. are performing lead-free assembly on roughly 10–20% of their total production. Larger EMS providers are establishing lead-free assembly parameters for OEMs, and implementing tasks forces and training programs to adapt to mixed-assembly lines. Beyond the science of lead-free assembly is the paperwork. Due diligence requires that manufacturers shipping end-product to California, China, the EU, and other regions disclose materials contained in an assembled board; each legislative regulation requires different levels of reporting. EMS providers must have a general knowledge of the reporting involved for product being shipped to various parts of the world to run a business efficiently and avoid fines and delivery delays that can wipe out profits. So, one year out, where are we? In China, of course.

China RoHS brings a new set of materials disclosure rules to the fore. Unlike EU RoHS, China's directive recommends material declarations on a "macro" scale, according to Krista Botsford of 5-Trees LLC. Therefore, the same product with requisite material declarations for PCB, components, surface finishes, connector wires, solder, etc., that meet EU standards would require only one or two material declaration sheets to be sold in China. Manufacturers must mark the entire assembly as containing/not containing lead, cadmium, etc. Declarations to the "homogeneous" level don't apply below 4mm^3, but Phase II government-sponsored testing regime applied to all selling product in China counterbalances looser regulations on material forms. Many worry that China does not have enough certified labs to perform destructive testing on all imports and domestic electrical and electronic products. Some components manufacturers are lax in reporting changes to terminations and surface finishes, so the assembler must practice due diligence to verify that the assembly on paper matches the assembly being shipped, says Nihal Sinnadurai, Ph.D., of ATTAC. An implementation date for the testing and materials verification phase of China RoHS has yet to be determined, and China's obstacles include the scarcity of certified testing labs, determination of products under Phase II scope, and other necessary industry guidelines. Assemblers shipping boards to China for final assembly only need not adhere to China RoHS, but any end product sold on China's market will require disclosure, and eventually testing; and OEMs will expect EMS providers to supply the necessary forms. SMT

— Meredith Courtemanche, SMT assistant editor

will continue to implement legislation. By 2010, every major industrialized nation will have its own version of RoHS and WEEE. British Columbia may join the regional emissions platform mentioned above. Japan's Law Concerning the Rational Use of Energy increasingly promotes energy efficiency in buildings, factories, and machinery, as well as equipment; Korea's legislation addressing toxicity, recyclability, and packaging will take effect January 1, 2008.

Economically developing nations will follow suit. The World Bank estimates that it would take 8% of China's GDP to address its environmental problems. In that vein, expect more environmental legislation from China, such as the promulgation of China WEEE's Directive, a draft of which was recently issued by the country's National Development and Reform Commission. In addition, we should expect more aggressive EPR Directives in regards to hazardous materials and recyclability from Brazil, Argentina, Mexico, and other nations.

Design-for-environment (DfE) implementations will accelerate. No one wants to duplicated the time, cost, and stress associated with RoHS and/or WEEE compliance. It is no surprise, therefore, that many manufacturers are looking to DfE implementations that simultaneously address toxicity, recyclability, energy efficiency, and other environmental aspects.

"Data, data, data" will become the electronics industry's mantra. With the growing need to conduct life-cycle analyses, provide ecological profiles, submit products for China RoHS Phase 2 pre-market testing, and defend oneself vs. EU RoHS audits when they happen, this mantra will quickly expand to environmental as well as financial factors. Among the datasets that increasingly will be required are:

- Energy usage: 14 working groups currently are determining product baselines for EuP.
- Greenhouse gas emissions: With the publication of recent reports, climate change has moved from debate to solution. Among solutions most advocated is a greenhouse gas emissions cap-and-trade system. At the World Economic Forum in Davos, Switzerland, in January 2007, 71% of attendees (primarily C-level executives) favored a mandatory system.
- Substance-level data: There is a major shift in companies seeking environmental-legislation consulting. A year ago, companies were content with Y/N RoHS Certificates of Compliance (CoCs), a focus on the RoHS 6 or 15 JIG-A substances, and a multi-month delay in ERP software updates that enabled parts management at the material and substance levels. Currently, they are demanding substance-level parts-per-million (ppm) data from suppliers; addressing a broader materials-of-concern list that reduces their exposure; and licensing substance-level database management software that they can implement quickly and use to generate the type of substance-level reports increasingly required for customers and government authorities (Figures 2 and 3).

Material and Substance Composition Report

Top Level Item: [PCBA_00743]

Item Status: **EU RoHS Compliant**

Item/Subitem Name	Homogeneous Material	Weight	Unit Of Measure	Level	Substance Category	Substance	CAS	Weight	Unit Of Measure	PPM	EU RoHS Exemption(s)
SMD Resistor [8080-8876-0000]	Middle Termination	0.062574	mg	B	Nickel/Nickel Compounds	Nickel	7440-02-0	0.0625736	mg	29240	5
	Marking	0.003552	mg	C	GROUP-C	Amorphous Silica	7631-86-9	0.0003638	mg	102410	
				C	GROUP-C	Titanium Dioxide	13463-67-7	0.0007276	mg	204819	
				C	GROUP-C	Epoxy Resin	129915-35-1	0.002461	mg	692771	
	Outer Termination	0.053115	mg	C	GROUP-C	Tin	7440-31-5	0.0531148	mg	1000000	
	Outer Overcoat	0.028013	mg	C	GROUP-C	Manganese Dioxide	1313-13-9	0.0008774	mg	31322	
				C	GROUP-C	Amorphous Silica	7631-86-9	0.0020544	mg	73338	
				C	GROUP-C	Cupric oxide	1317-38-0	0.002568	mg	91673	
				C	GROUP-C	Chromium Oxide	1308-38-9	0.0052644	mg	187930	
				C	GROUP-C	Epoxy Resin	129915-35-1	0.0172484	mg	615737	
	Inner Overcoat	0.015237	mg	C	GROUP-C	Amorphous Silica	7631-86-9	0.0045796	mg	300562	
				C	GROUP-C	Boric Anhydride	1303-86-2	0.0030388	mg	199438	
				A	Lead/Lead Compounds	Lead (IV) oxide	1309-60-0	0.0076184	mg	500000	
	Resistive Film	0.019003	mg	C	GROUP-C	Amorphous Silica	7631-86-9	0.0038092	mg	200450	
				C	GROUP-C	Ruthenium dioxide	12036-10-1	0.006634	mg	349099	
				C	GROUP-C	Boric Anhydride	1303-86-2	0.001926	mg	101351	
				A	Lead/Lead Compounds	Lead (IV) oxide	1309-60-0	0.006634	mg	349099	
	Inner Electrode Bottom	0.025209	mg	C	GROUP-C	Boric Anhydride	1303-86-2	0.0004708	mg	18676	
				C	GROUP-C	Amorphous Silica	7631-86-9	0.0004708	mg	18676	
				C	GROUP-C	Silver	7440-22-4	0.02354	mg	933786	
				A	Lead/Lead Co	Lead (IV) oxide	1309-60-0	0.0007276	mg	28862	
	Inner Electrode Top	0.037493	mg	C	GROUP-C	Amorphous Silica	7631-86-9	0.000749	mg	19977	
				C	GROUP-C	Silver	7440-22-4	0.034668	mg	924658	
				C	GROUP-C	Palladium	5/3/7440	0.0009416	mg	25114	
				A	Lead/Lead Compounds	Lead (IV) oxide	1309-60-0	0.000749	mg	19977	
				C	GROUP-C	Boric Anhydride	1303-86-2	0.0003852	mg	10274	
	Inner Electrode Side	0.000642	mg	C	GROUP-C	Chromium	7440-47-3	0.000321	mg	500000	
				B	Nickel/Nickel Compounds	Nickel	7440-02-0	0.000321	mg	150	
	Substrate	1.888944	mg	C	GROUP-C	Aluminum Oxide	1344-28-1	1.817074	mg	961952	
				C	GROUP-C	Magnesium Oxide	1309-48-4	0.015194	mg	8044	
				C	GROUP-C	Silicon Dioxide	14808-60-7	0.05671	mg	30022	
Resistor [8080-8874-0000]	Glass	0.014935	mg	C	GROUP-C	Frits, chemicals	65997-18-4				
	Silver	0.037955	mg	C	GROUP-C	Silver	7440-22-4	0.037955	mg	1000000	

Figure 3. Top-level product substance disclosure report.

Conclusion

In the 1990s, Geoffrey A. Moore's book, *Crossing the Chasm*, reported that most companies were in the center of the bell curve when it came to adopting new technologies. The same is true when it comes to adopting "green" practices. But with mounting financial pressure from governments, customers, and competitors, these companies are on the verge of going green.

Given the speed of greening, the large number of unaware companies, and thin corporate margins, there is a strong likelihood that a greater-than-usual number of companies will not survive. The upshot of future environmental trends is that it makes business sense to ride the greening of our industry to your advantage. Whatever your perspective, take it seriously. Revenues, customers, and jobs are at risk. A few key components to keep in mind are:

- When making capital improvements, think in terms of ECTs.
- Track greening trends to avoid being blindsided. Count on these trends impacting your business.
- Escalate compliance activities into a strategic DfE program.
- Gather hard data regarding energy efficiency, materials, and substances; gather the tools to best manage, analyze, roll-up, and report the data.
- Shift from a "have-to comply" to a "want-to comply, competitive advantage" mindset. There is a great deal of money to be made from providing greener products and services. SMT

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